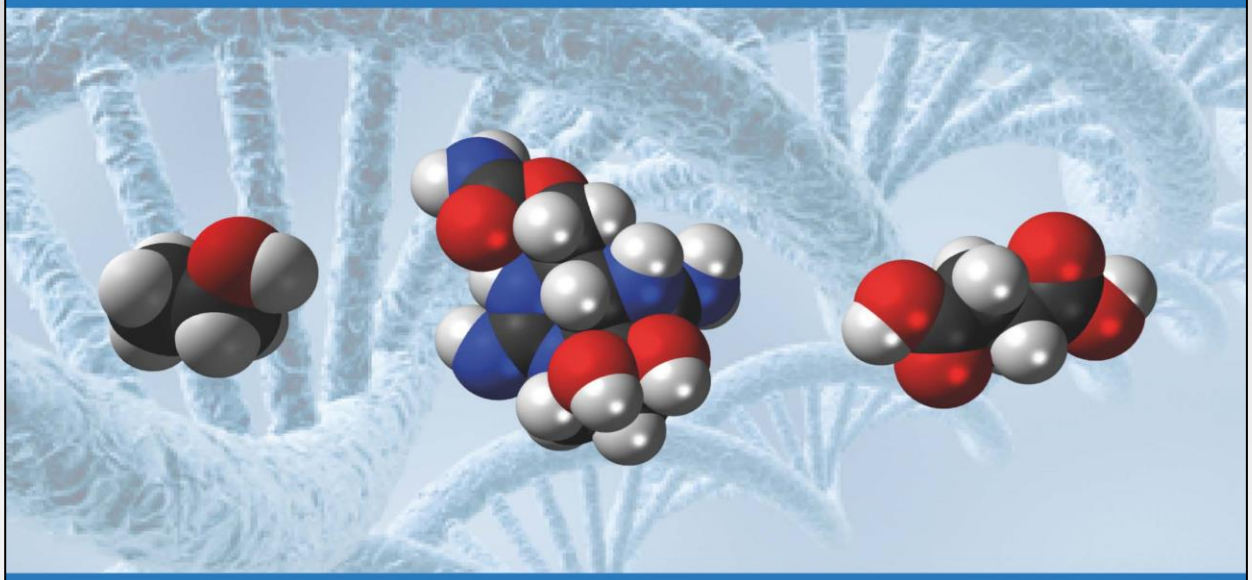
19th Conference of the States Parties



Science for Diplomats

The Science of the Bioeconomy

Jonathan E. Forman, Ph.D.
Science Policy Adviser
Office of Strategy and Policy
OPCW

Dr. Henrike Gebhardt
Senior Project Manager Bioeconomy
Corporate Innovation Strategy & Management
Evonik Industries AG

SAB Report of the Developments in S&T to The Third review Conference

(RC-3/DG.1, Dated 29 October 2012)

Director General's Recommendations

(RC-3/DG.2, Dated 31 January 2013)

Response to the Report of the Twenty-First Session of the Scientific Advisory Board

(EC-77/DG.10, Dated 5 September 2014)

Status of the Follow-Up to the Recommendations on S&T to the Third Review Conference

(EC-77/DG.11, Dated 5 September 2014)

The Temporary Working Group on Convergence

(see EC-77/DG.10, dated 5 September 2014 for Director-General response to recommendations)

Recommendations from the TWG on Convergence

- 19 Recommendations presented in report; **Status in EC-77/DG.10**
- Continue to **monitor** advances and trends in **production technologies** and assess the relevance of these processes to verification under the CWC.
- **Monitor** advances in **systems and synthetic biology**, particularly in terms of enhancing the capability and capacity to synthesise more complex chemicals.
- **Monitor** advances in **nanotechnology**, particularly as they apply to improved defensive countermeasures against CW.
- Consider **development of outreach materials** to assist States Parties in understanding possible implications for the CWC.
- Establish a structured approach to **maintain contact with the BWC community**.
- Consider re-activating the TWG on Convergence periodically, in order to assess recent advances

Chemistry Underpins Biology

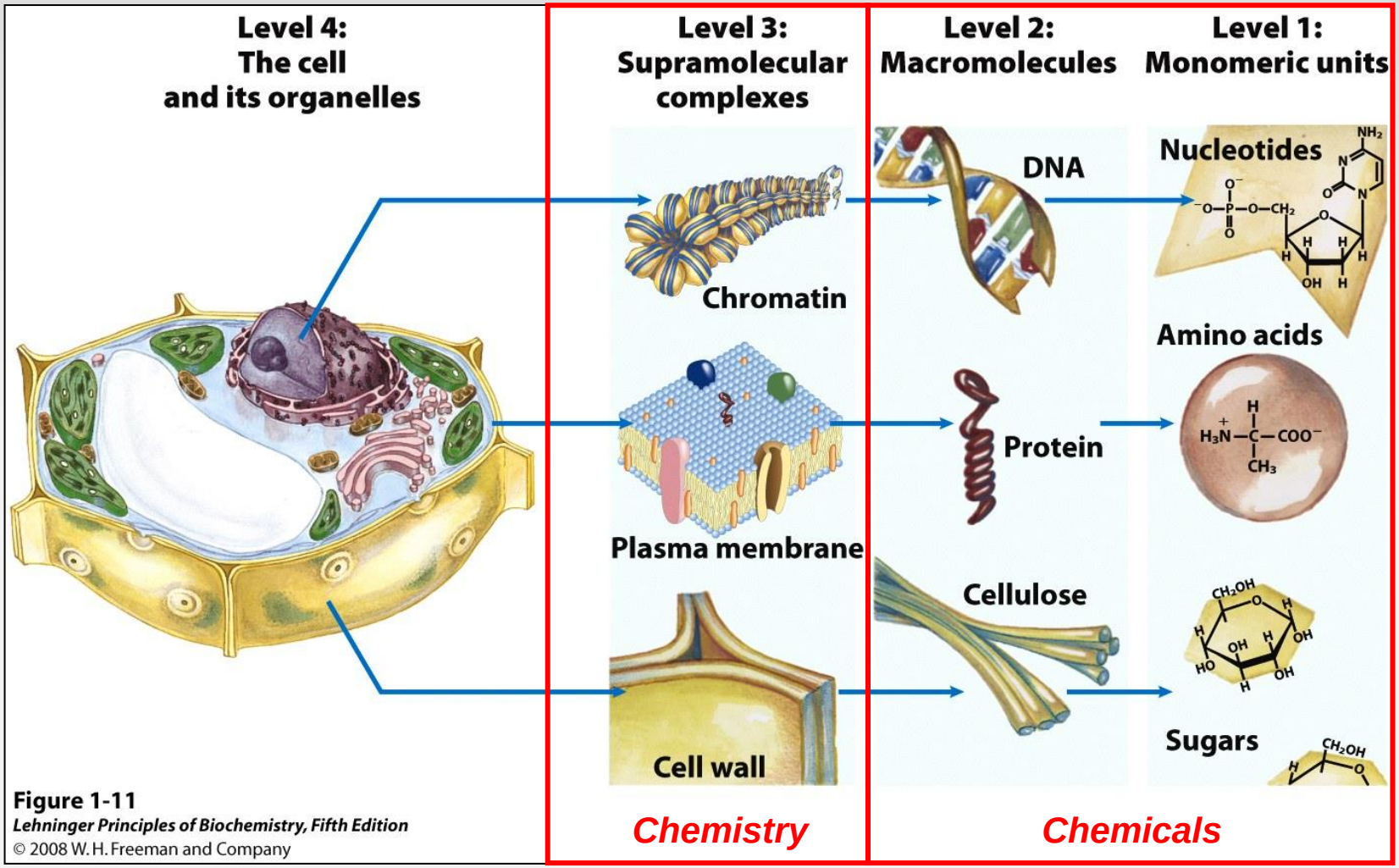
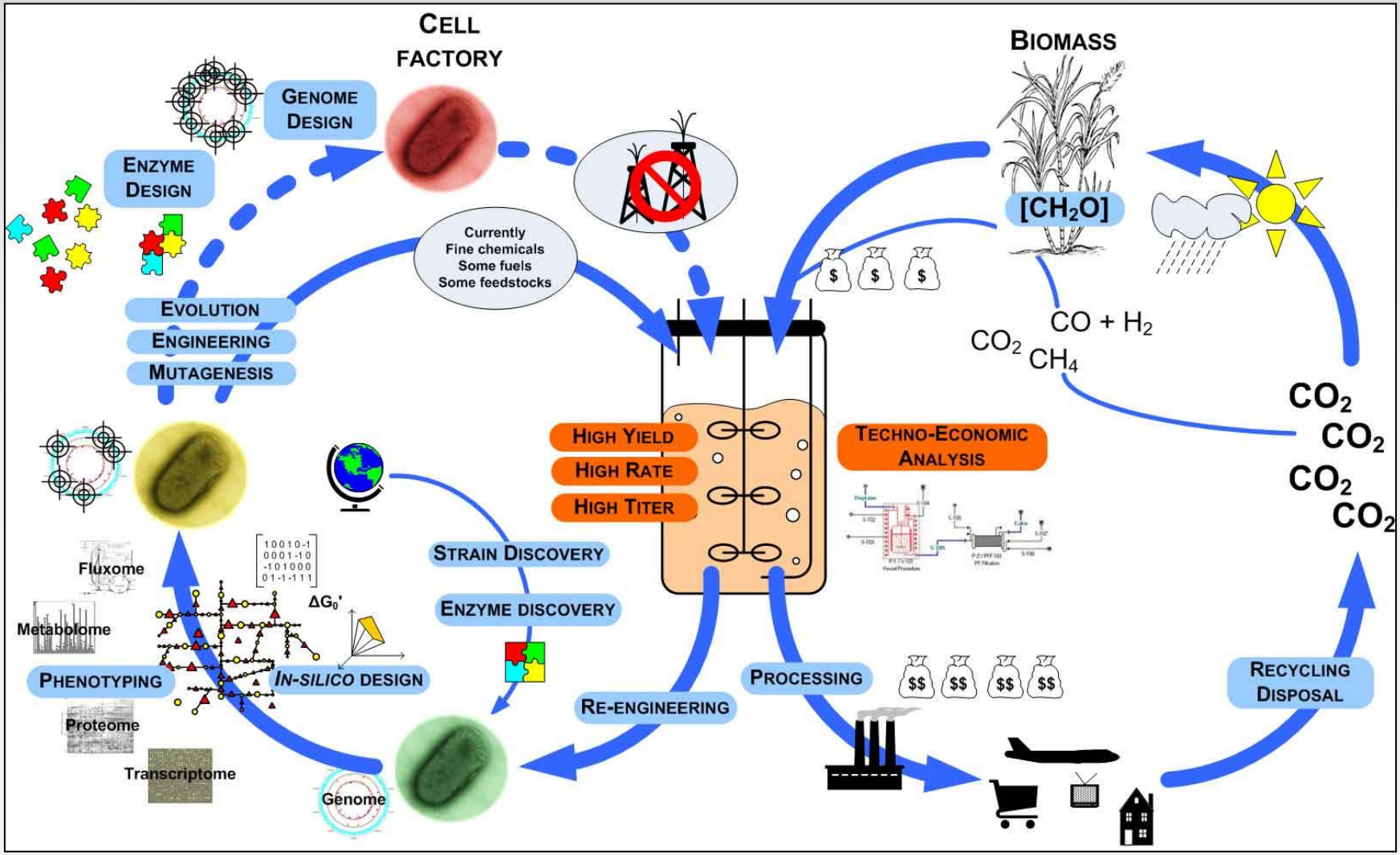
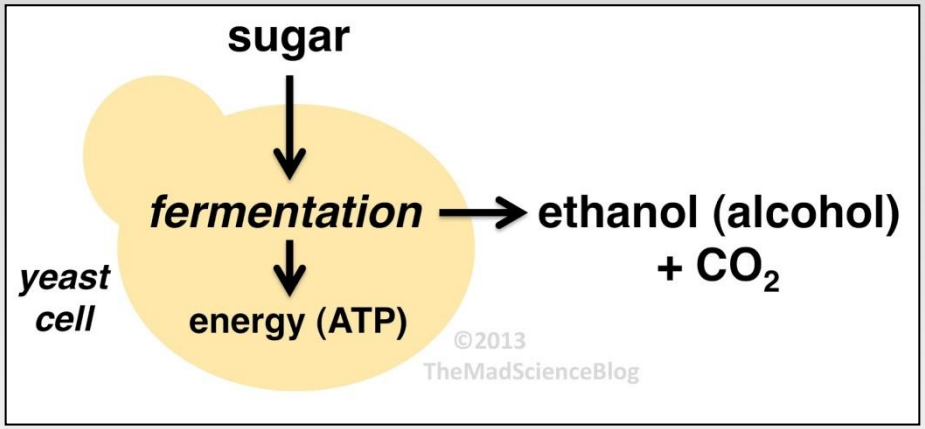


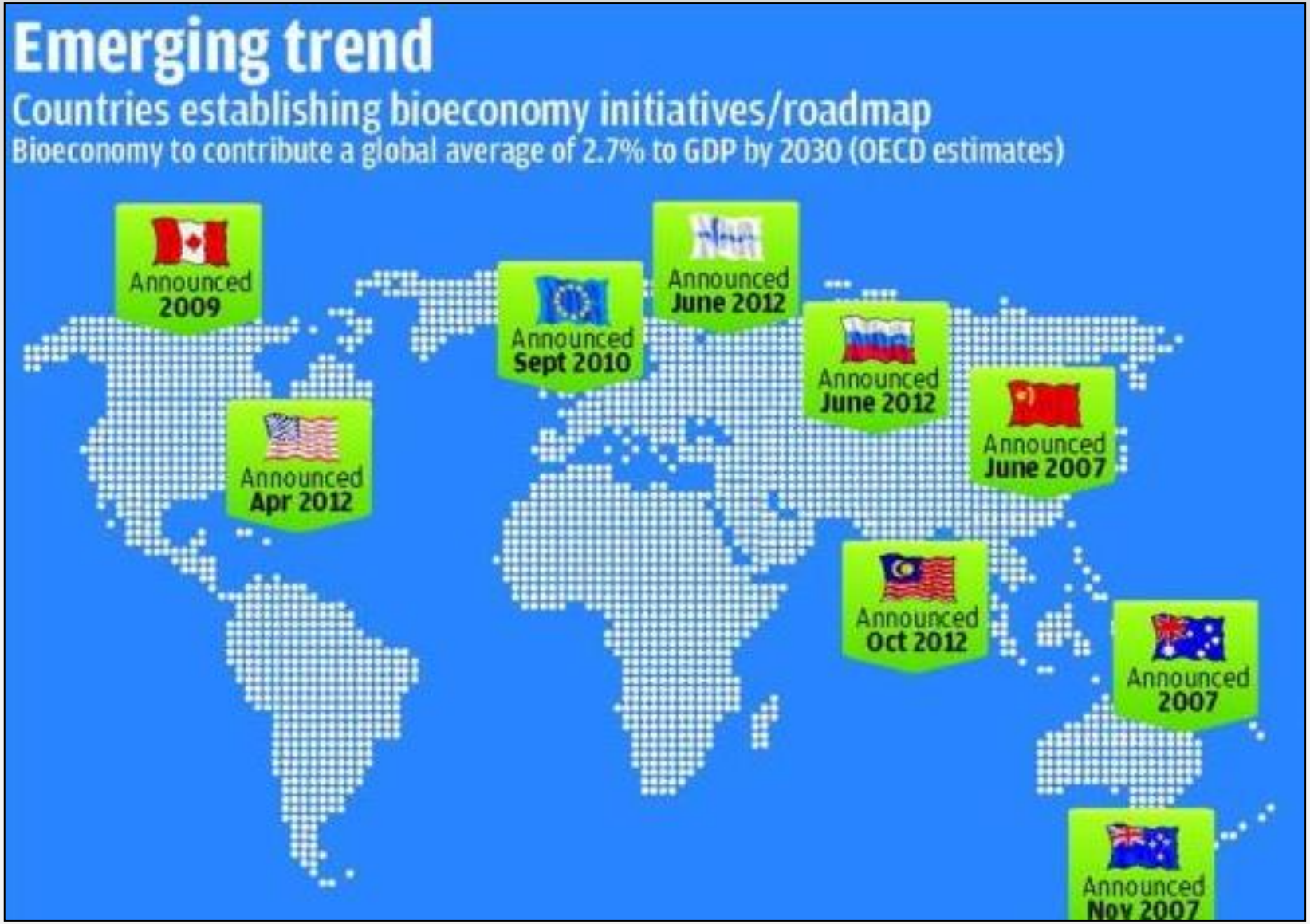
Figure 1-11
Lehninger Principles of Biochemistry, Fifth Edition

Bio-Mediated Chemical Production



Bio-Mediated Chemical Production: The Basics




Emerging trend
Countries establishing bioeconomy initiatives/roadmap
Bioeconomy to contribute a global average of 2.7% to GDP by 2030 (OECD estimates)
Announced 2009
Announced Apr 2012
Announced Sept 2010
Announced June 2012
Announced June 2012
Announced June 2007
Announced Oct 2012
Announced 2007
Announced Nov 2007

The science of the Bioeconomy

Dr. Henrike Gebhardt

05 December 2014

EVONIK INDUSTRIES

Our positioning

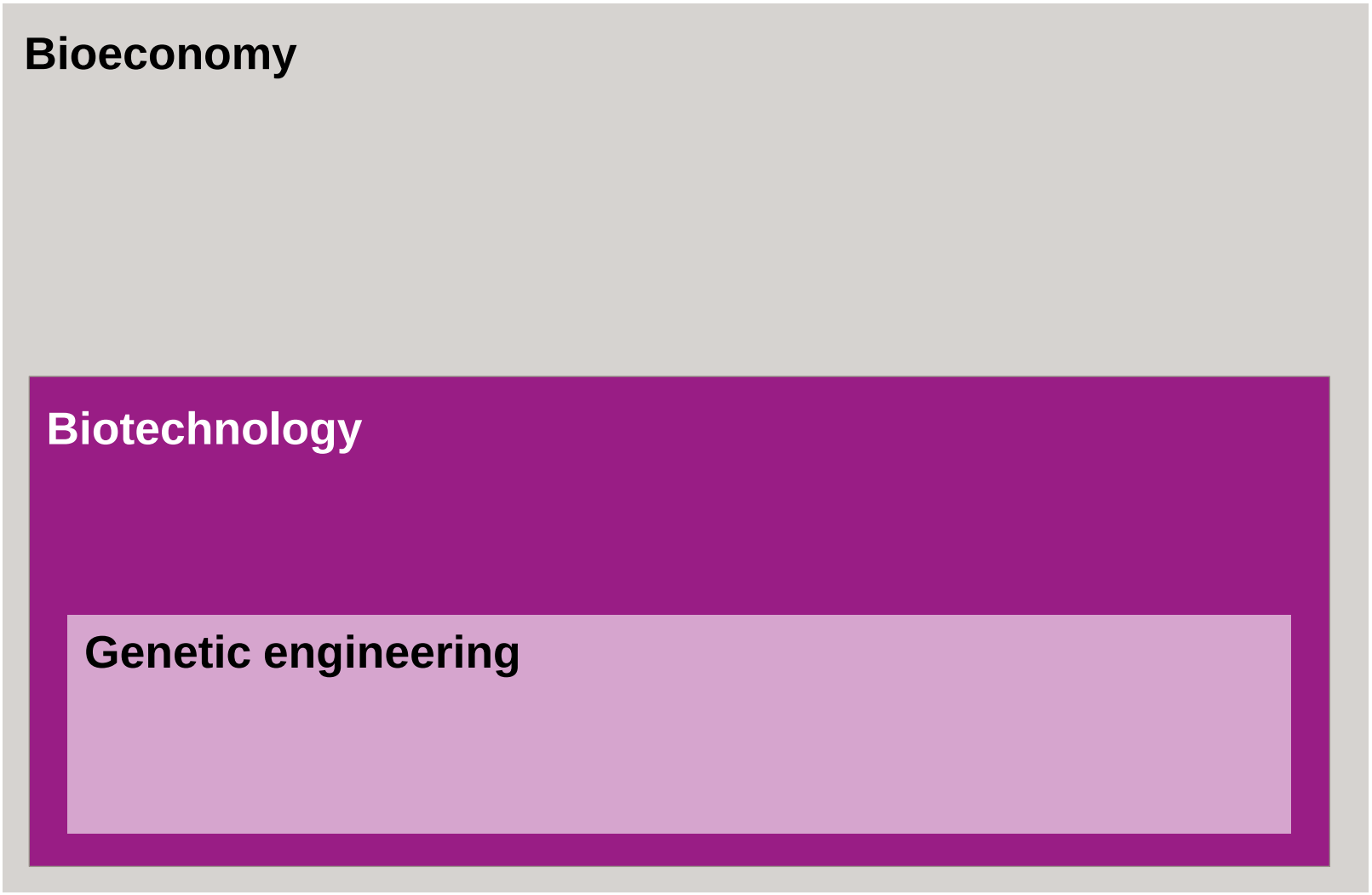
Evonik is the creative industrial group from Germany and one of the world’s leading specialty chemicals companies.

Our credo

The Bioeconomy is one driver to promote a more resource-efficient and sustainable economy.

Industrial biotechnology is a key technology for realising the bioeconomy.

Overview



Definitions

Bioeconomy

Production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, and other industrial products and energy. COM(2012) 60, EU Commission, mod.

Bio-based products

Products wholly or partly derived from biomass. EN 16575

Bio-based products offered by Evonik

bio-based

Polyamids

VESTAMID®*Terra*

Polyesters

DYNACOLL®*Terra*

DYNAPOL®*Terra*

VISIOMER®*Terra*

Additives

BioMTBE

Amino acids

Feed additives

Health – purified

Cosmetics

TEGOSOFT®MM

Additives

VISCOPLEX®
Series 10

Cleaning

Esterquats

Health

RESOMER®

bio-degradable

Evonik invests in high-growth chemical megatrends

Lighthouse investment projects

Lysine
Russia

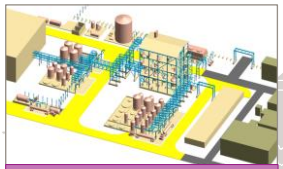
Consumer Specialties
China

C4 Chemistry
Europe

H_2O_2 / HPPO
China

Lysine Expansion
USA

Crosslinkers, Isophorone
China



Consumer Specialties
Brazil

Superabsorbents
Saudi Arabia

Methionine
Singapore

Biodiesel catalysts
Argentina

Lysine
Brazil

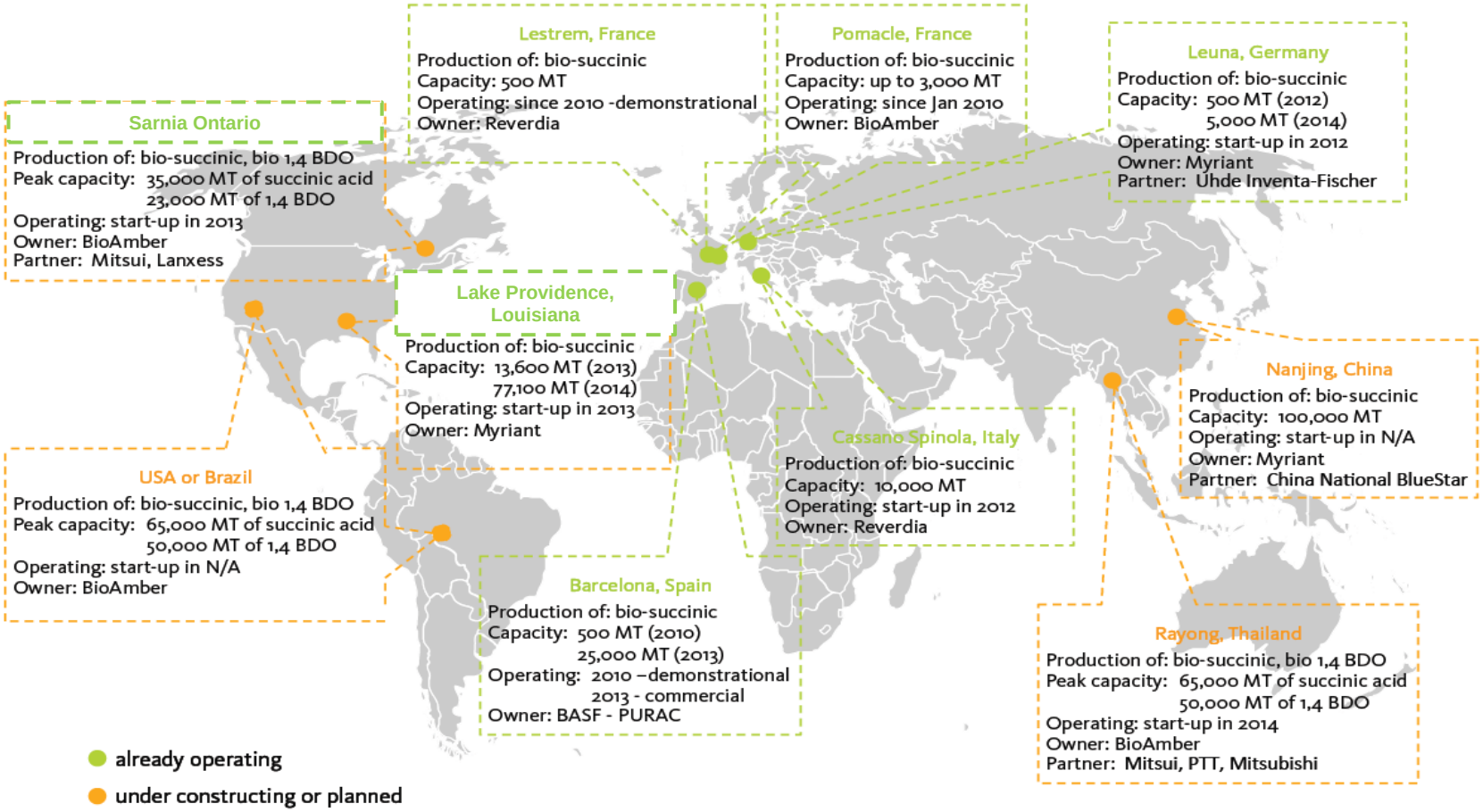
Bioeconomy

Traditional

Bioeconomy
Press releases

Company Date of Issue	Raw Material	Intermediate Volume	Product Commissioning
DSM/POET (USA) Jan 2012	Cellulosics from corn cobs	Ethanol 90 kta	Biofuels H1.2014
Purac/BASF (ES) Mar 2014	Cellulosics	Succinic acid 10 kt	e. g. Biopolymers 03.2014
Solvay/NBE (US) Mar 2014	Sawmill residues	Torrefied biomass 250 kt	Substitute coal Q4.2014
LanzaTech (USA) Aug 2010	Wood residues (syngas)	Ethanol 15 kt	Biofuels 2014
Butamax (USA) Oct 2013	Corn mash	Butanol ~180 kt	Biofuels 2015

Commercializing bio-based succinic acid technology – first operating plants in Europe, expansion in Asia/Americas



Source: Determination of market potential for selected platform chemicals, weastra, 2012

Europe will depend on import of renewable carbon sources

Expected biomass trade routes by 2020, TWh

Source: World economic forum 2010; the future of industrial biorefineries

Overview

Bioeconomy

Bio-based products

Products wholly or partly derived from biomass. EN 16575

Biotechnology

Genetic engineering

Technologies

Bioeconomy

Bio-based products
can be produced by conventional chemical processes or by biotechnology

Biotechnology

The use of living organisms or their components to make products.

Genetic engineering

Bio-based products offered by Evonik

bio-based

bio-processed

bio-degradable

Polyamids

VESTAMID®*Terra*

Polyesters

DYNACOLL®*Terra*

DYNAPOL®*Terra*

VISIOMER®*Terra*

Additives

BioMTBE

Amino acids

Feed additives

Health – purified

Cosmetics

TEGOSOFT®MM

Additives

VISCOPLEX® Series 10

Cleaning

Esterquats

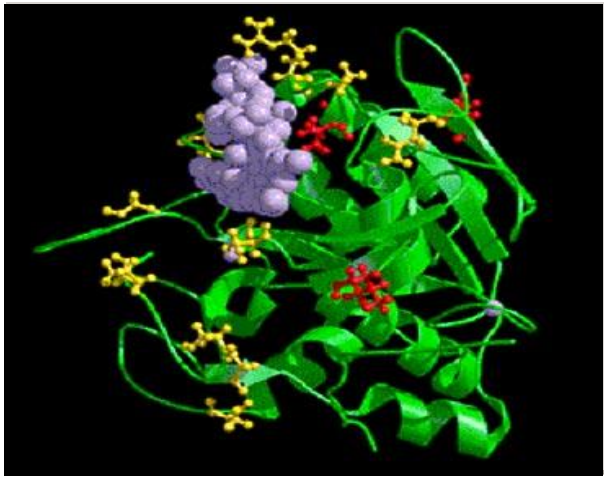
Health

RESOMER®

Biotechnological processes

Bio-catalysis:

use of natural catalysts such as isolated enzymes or whole-cells to perform chemical transformations



Fermentation:

use the metabolism of a whole living cell to produce substances e.g. chemicals

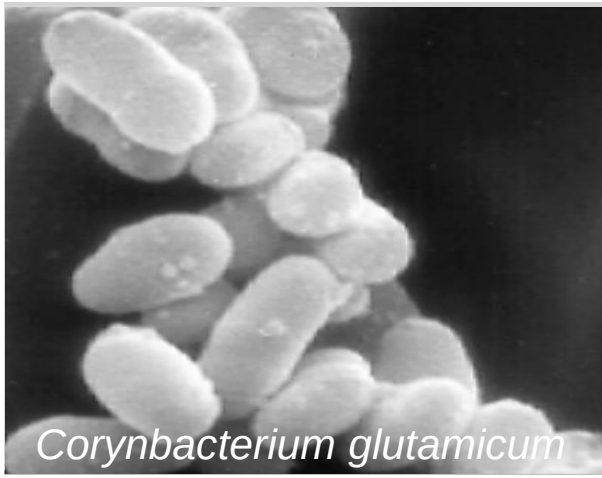
Performed in bio-reactor or fermenter

Bio-reactor - Production

Living Cells

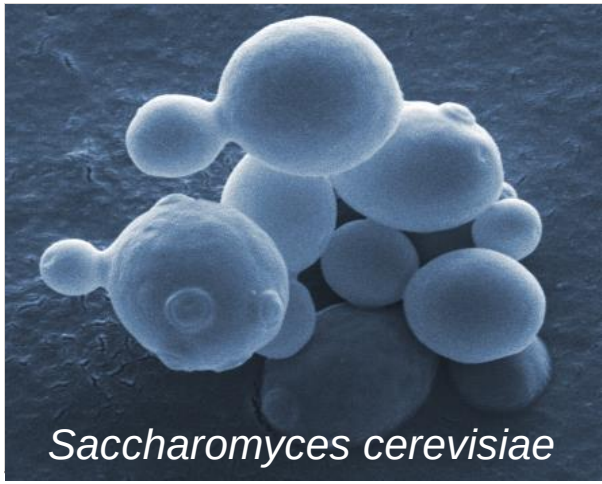
Micro-organisms

- Bacteria e. g. *Corynbacterium glutamicum*
  Product: sodium-glutamate, flavour enhancing compound, umami taste of food
- Yeast e. g. *Saccharomyces cerevisiae*
  Product: bread, beer

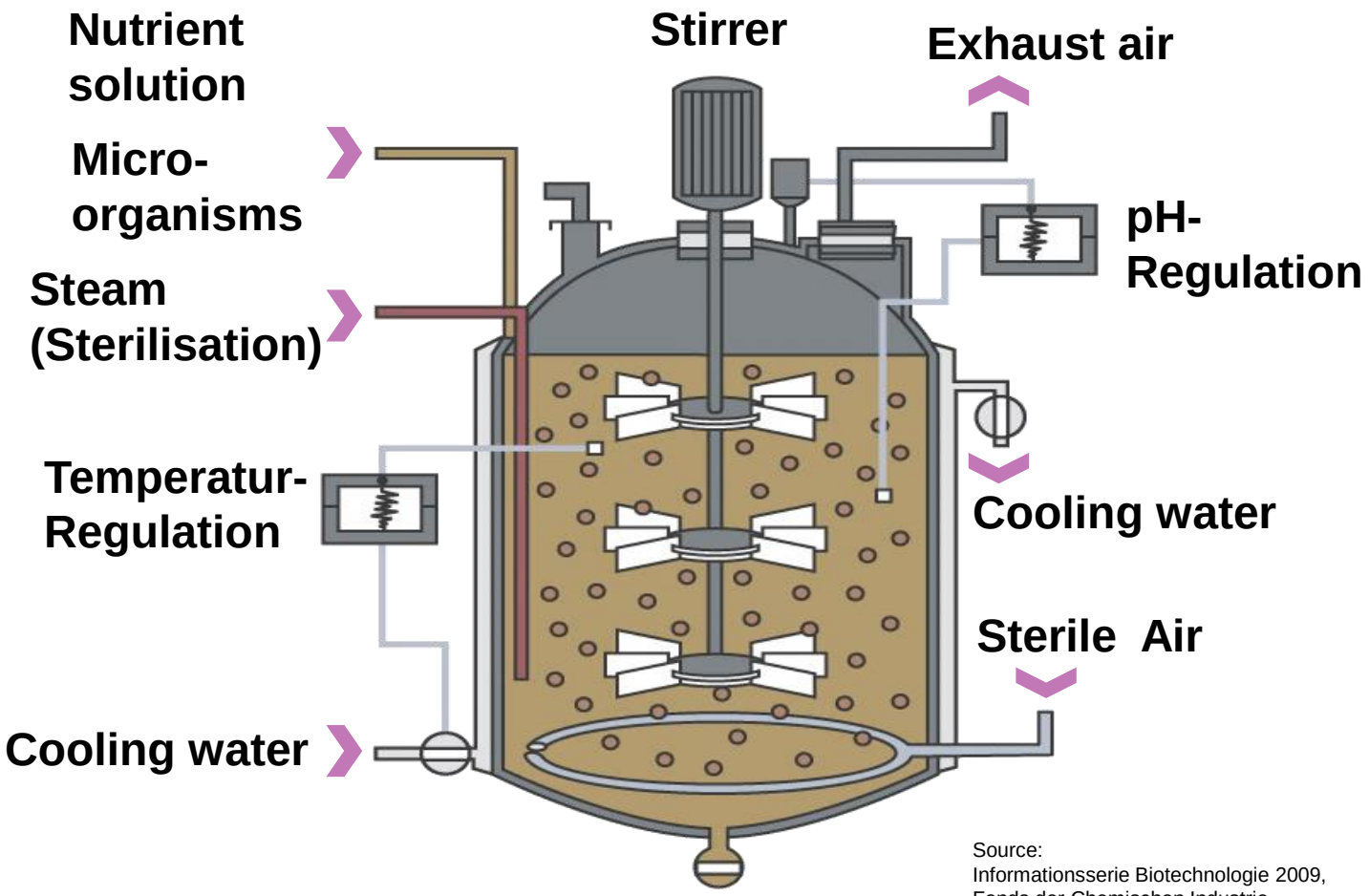

Corynbacterium glutamicum

Higher Organisms

Cells of mammals, humans, insects, plants


Saccharomyces cerevisiae

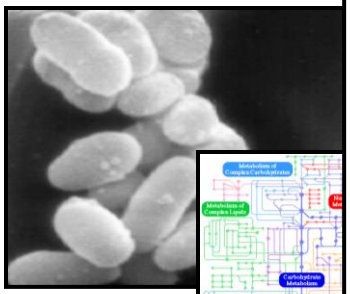
Bio-reactor - Principle



Source:
Informationsserie Biotechnologie 2009,
Fonds der Chemischen Industrie.

Example:
Fermentation to produce amino acids

Sugar → Fermentation → **Amino acid L-lysine** → Feed additive



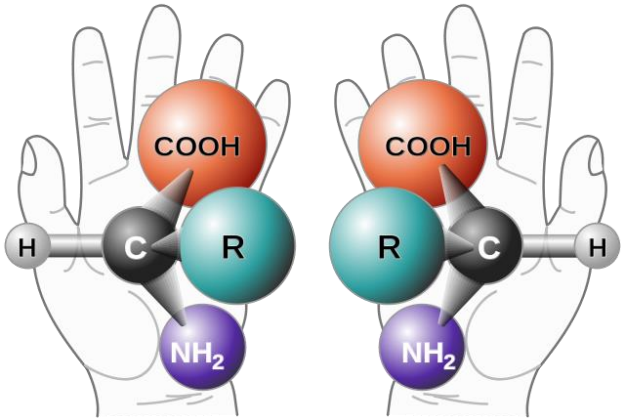
Advantages of biotechnology compared to chemical synthesis

Specificity and selectivity

Final product derived directly, not via intermediate

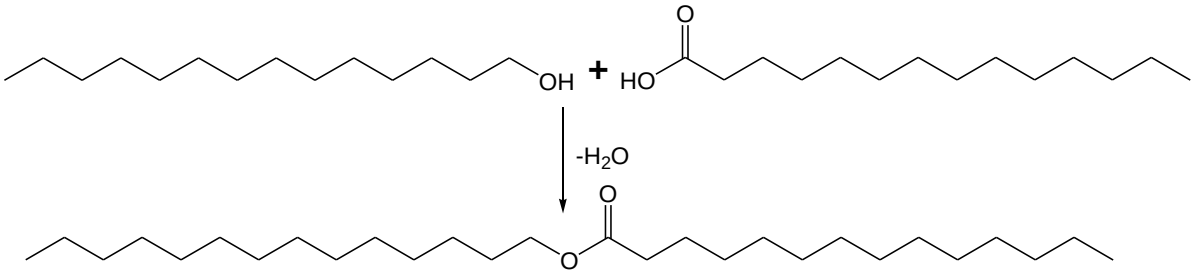
Stereoselective synthesis of chirale compounds
e. g. only L-amino acid, no D-amino acid

- no racemates (mixture of D/L)
- no complex separation process
- no impurities in final product

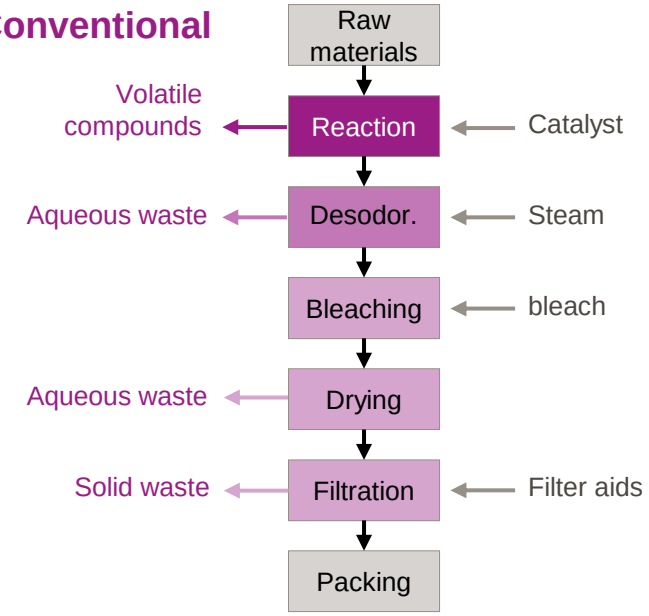


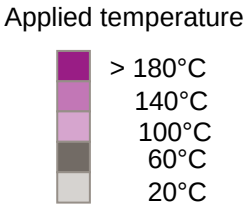
Source: Wikimedia Commons

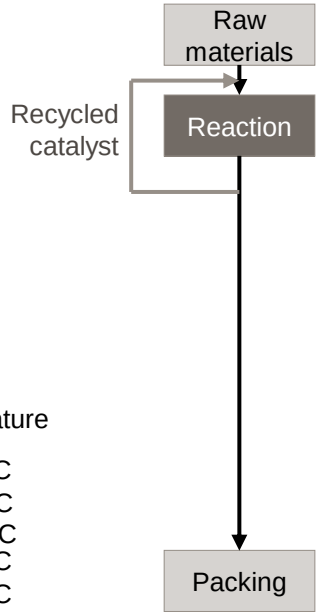
Sustainability that goes under the skin: Myristyl myristate for cosmetics



Conventional







Enzymatic - Biocatalysis

- **Less steps**
- **Lower temperatures**
- **Less energy**
- **Less waste**
- **More resource efficiency**

Advantages of biotechnology compared to chemical synthesis

Specificity and selectivity

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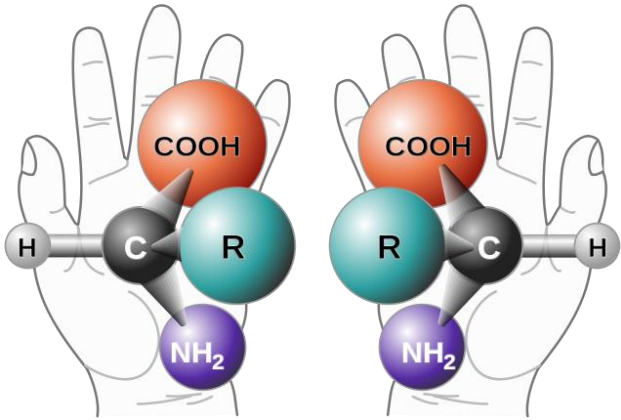


Source: Wikimedia Commons

Efficiency and environmental sustainability

- Economic / safe feedstocks: water, sugar, air, salts
- Mild / safe process conditions: room temperature, atmospheric pressure, medium pH
- Less energy needed, less waste produced

Technologies

Bioeconomy

Bio-based products can be produced by conventional chemical processes or by biotechnology

Biotechnology

The use of living organisms or their components to make products.

Genetic engineering

Any of various applications of biological science used in the manipulation of the genome of an organism

The Genome

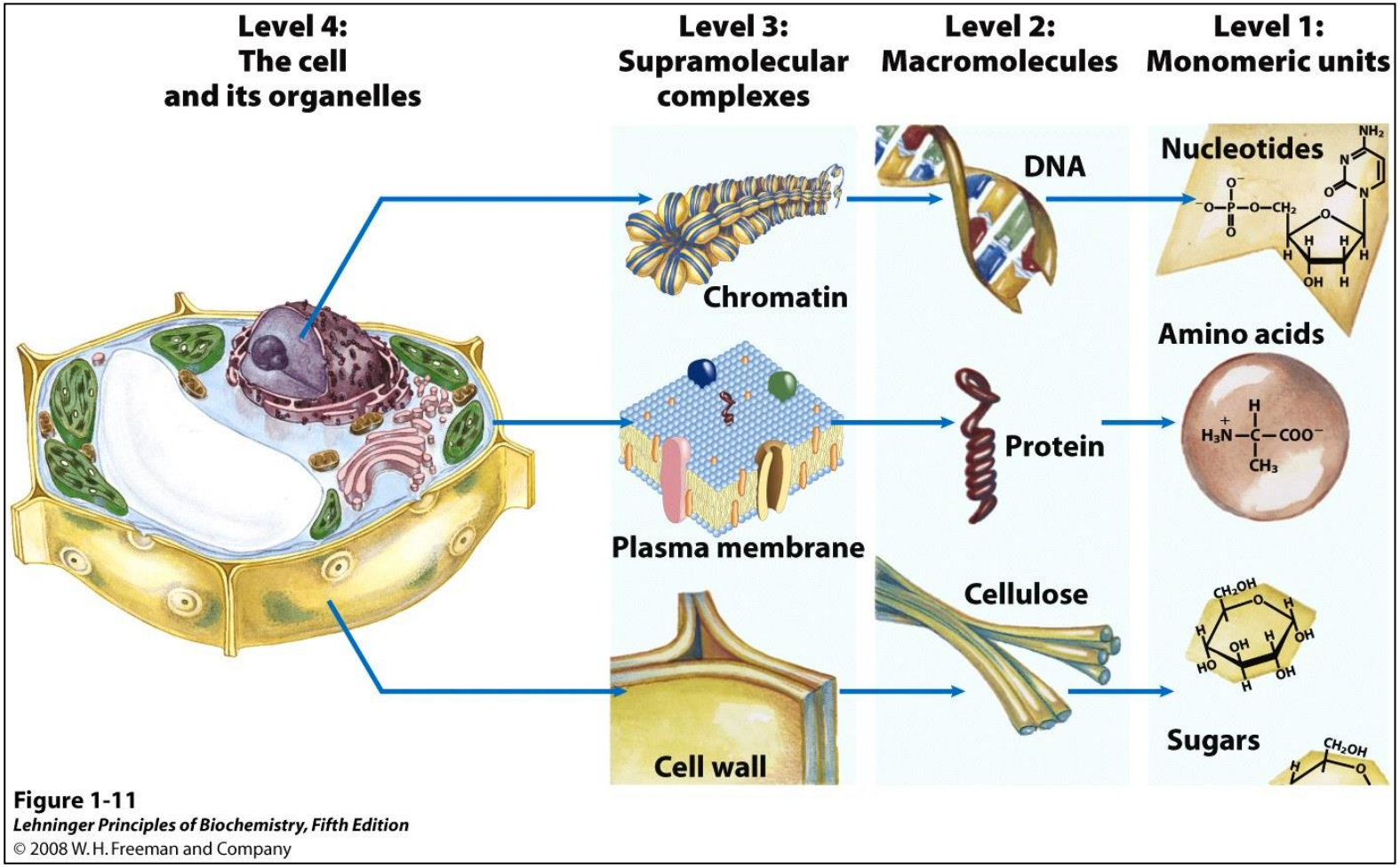
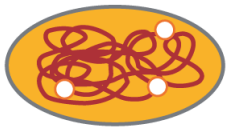


Figure 1-11
Lehninger Principles of Biochemistry, Fifth Edition

Genetic engineering methods to generate producing strain

Mutagenesis

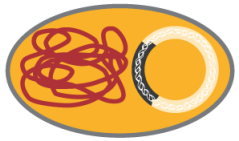
Chemicals
or radiation



Exchange of nucleotide

Recombination

Availability of 10^{11} genes
(biodiversity)
Recombination in vector



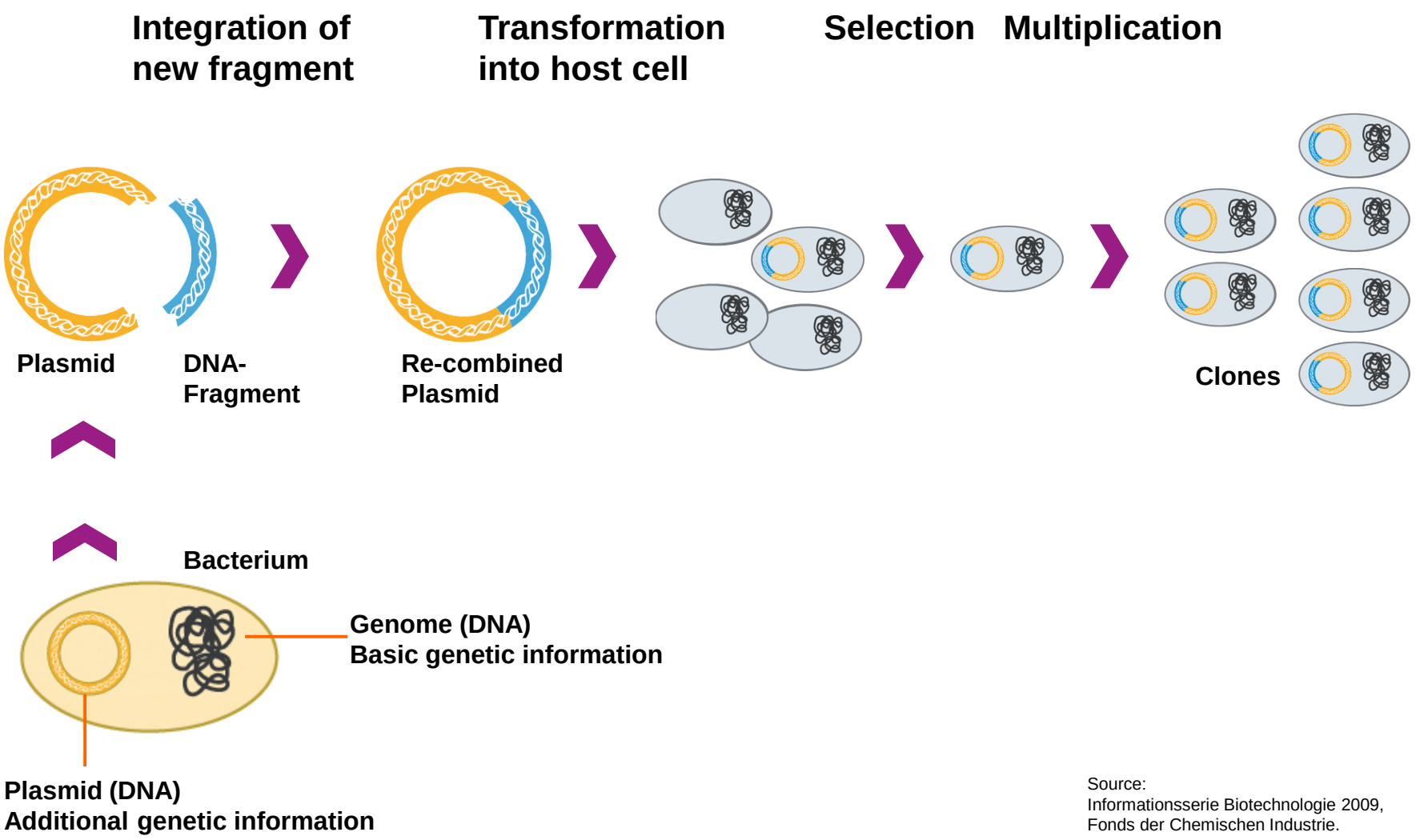
Additonal gene

Selection of desired property

Producing strain

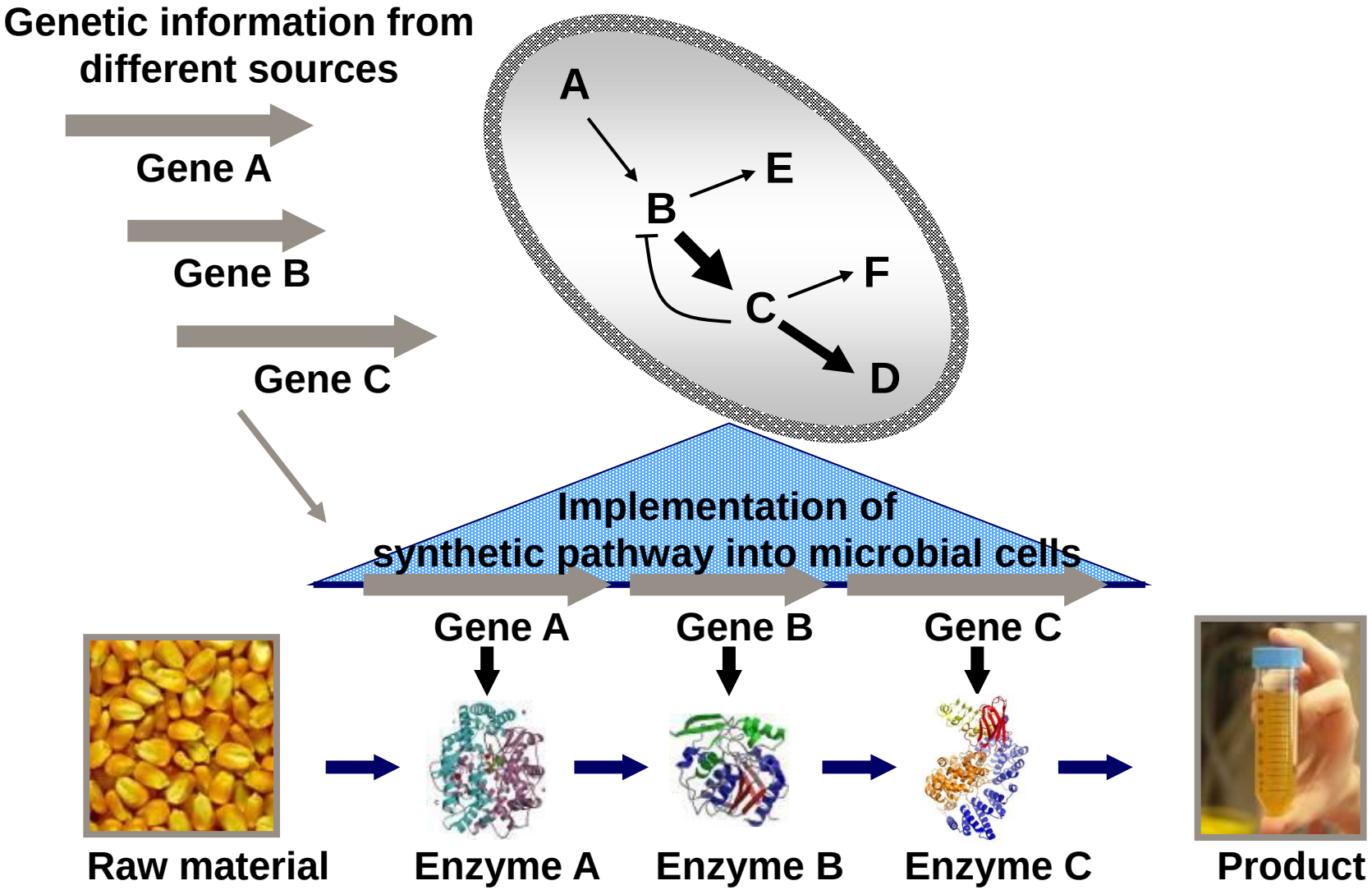
Source:
Informationsserie Biotechnologie 2009,
Fonds der Chemischen Industrie.

Recombination of DNA and transformation into bacterial cell

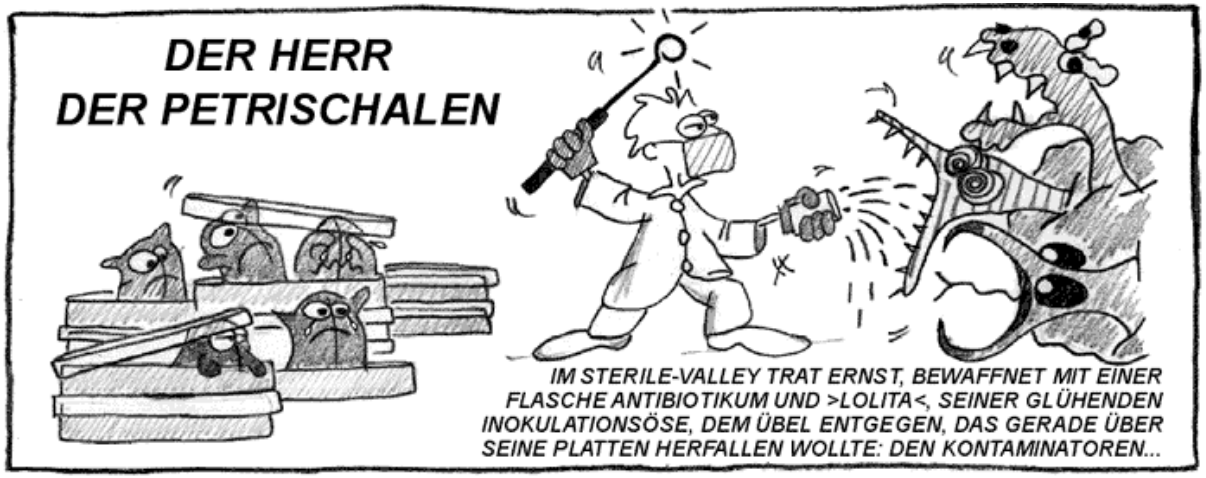


Source:
Informationsserie Biotechnologie 2009,
Fonds der Chemischen Industrie.

Cell factories
to provide customized precursors

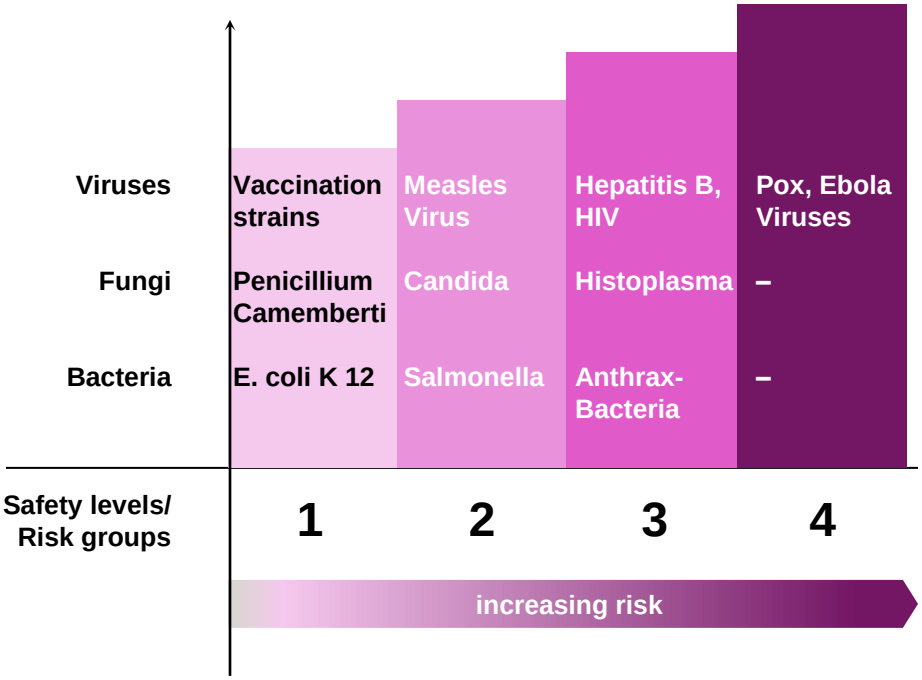


Is genetic engineering dangerous?



Risk Groups and Biosafety Level Definitions

Risk Groups (World Health Organization)



Biosafety Levels

Safety Level	Description
S1	no or low individual and community risk
S2	moderate individual risk, low community risk
S3	high individual risk, low community risk
S4	high individual and community risk

Source: Informationsserie Biotechnologie 2009, Fonds der Chemischen Industrie.

Potential chemical weapons from living organisms: Toxins

- Use of toxins is covered by
  - 1925 Geneva Protocol
  - Biological and Toxin Weapons Convention of 1972
  - Chemical Weapons Convention
- Toxins are poisons produced by living organisms e.g. bacteria, fungi, algae and plants
- Toxins are peptides, proteins or low-molecular organic compounds
- Toxins are less suitable for dispersal on a large scale. Nonetheless, they could be used for sabotage or in especially designed inputs, e.g. against key persons.
- Most toxins are unstable in alkaline water solutions and are thus easily destroyed by means of normal decontamination methods.

Source: A FOA Briefing Book on Chemical Weapons.

Examples
Bacterial Toxins

Botulinum toxin

produced by *Clostridium botulinum,* causes a severe form of food-poisoning (botulism),
used in treating squinting and other muscular disorders.

Staphylococcus enterotoxin type B

produced by *Staphylococcus aureus,*
causes food-poisoning symptoms

Saxitoxin

produced by blue-green algae (*cyanobacteria*) which are food for mussels,
attacks the nervous system and has a paralyzing effect,
included in Schedule 1 of the CWC

Source: A FOA Briefing Book on Chemical Weapons.

Examples
Plant Toxin and Bioregulators

Plant Toxin

Ricin extracted from seeds of the castor oil plant or produced by *E. coli*,
blocks the body's synthesis of proteins, death frequently occurs through heart failure,
included in Schedule 1 of the CWC

Bioregulators

No toxins, but possible use is similar

Example: Substance P, a polypeptide,
causes a rapid loss of blood pressure which may cause unconsciousness

Source: A FOA Briefing Book on Chemical Weapons.